

Amortized Inference of Neuron Parameters on Analog Neuromorphic Hardware

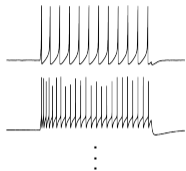
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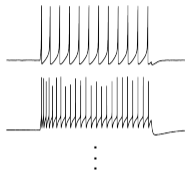
26. March 2026

Neuro Inspired Computational Elements Conference, Atlanta, USA

Observations x^*

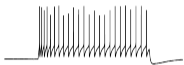
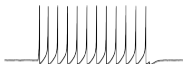


Observations x^*



Model \mathcal{M}

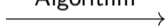
$$C_m \frac{dV_m(t)}{dt} = g_L \cdot (V_L - V_m(t)) + I(t)$$

Observations x^* 

⋮

Model \mathcal{M}

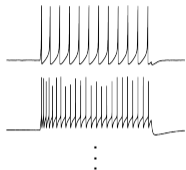
Algorithm

**Parameters θ**

[1.2, 4.6, ...]

[2.9, 7.1, ...]

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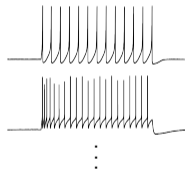
Observations x^* **Model \mathcal{M}**

Algorithm →

Parameters θ

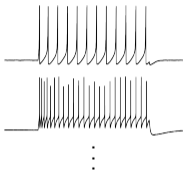
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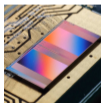
 $\mathcal{M}(\theta)$ →**Model Output x'** 

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Observations x^*



Model \mathcal{M}



BrainScaleS-2

SBI

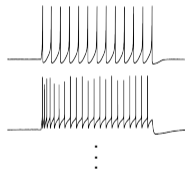
Parameters θ

[1.2, 4.6, ...]

[2.9, 7.1, ...]

$\mathcal{M}(\theta)$

Model Output x'



Model:AdEx neuron on **BrainScaleS-2**

- analog neuron circuits
- adaptive exponential integrate-and-fire neuron model:

$$C_m \frac{dV_m(t)}{dt} = g_L \cdot (V_L - V_m(t)) + g_L \Delta_T \exp\left(\frac{V_m(t) - V_T}{\Delta_T}\right) + I_{\text{syn}}(t) + I(t) - w(t),$$

$$\tau_w \frac{dw(t)}{dt} = a (V_m(t) - V_L) - w(t),$$

 V_m crosses V_{th} :

$$V_m \rightarrow V_r$$

$$w \rightarrow w + b.$$

Model:

AdEx neuron on **BrainScaleS-2**

- parameters are controlled by a DAC with 10 bit resolution

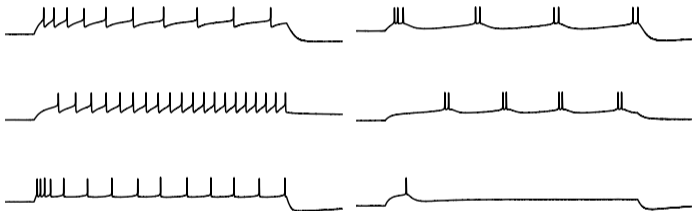
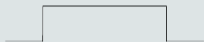
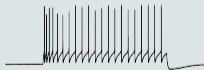


Figure adapted from S. Billaudelle *et al.*, presented at the 2022 29th IEEE International Conference on Electronics, Circuits and Systems (ICECS), pp. 1–4.

Model:AdEx neuron on **BrainScaleS-2****Input:**Step current: 1000 μ s**Output:**

- parameters are controlled by a DAC with 10 bit resolution

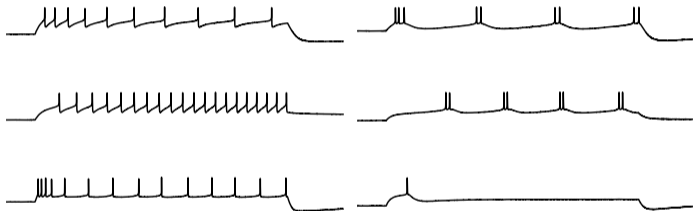
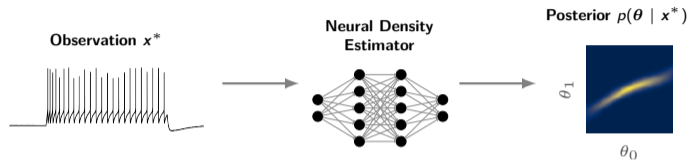
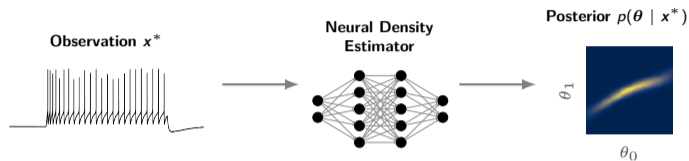
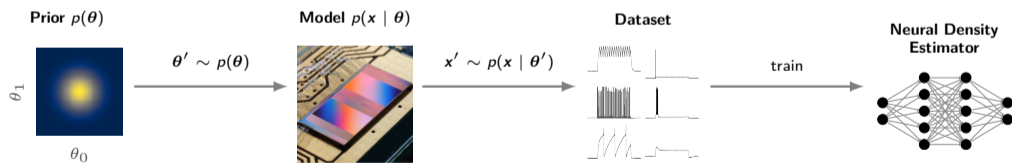


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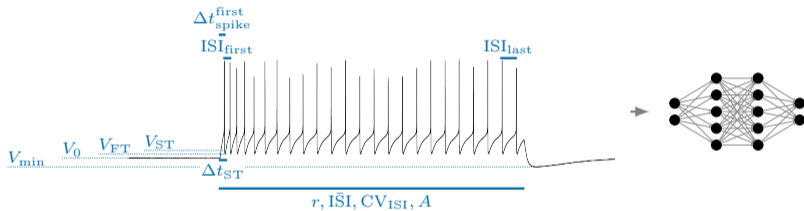


Training:



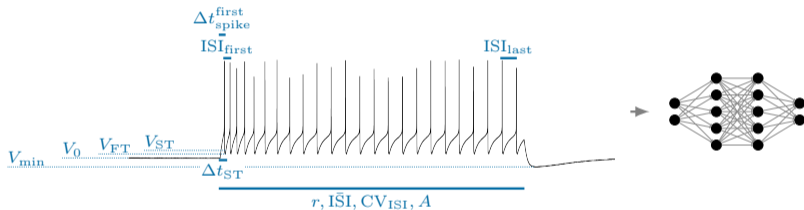
Feature Extraction

■ Features: 12 features

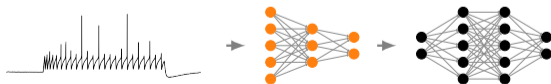


Feature Extraction

■ Features: 12 features



■ Summary Network: Convolutional-recurrent neural network trained together with NDE

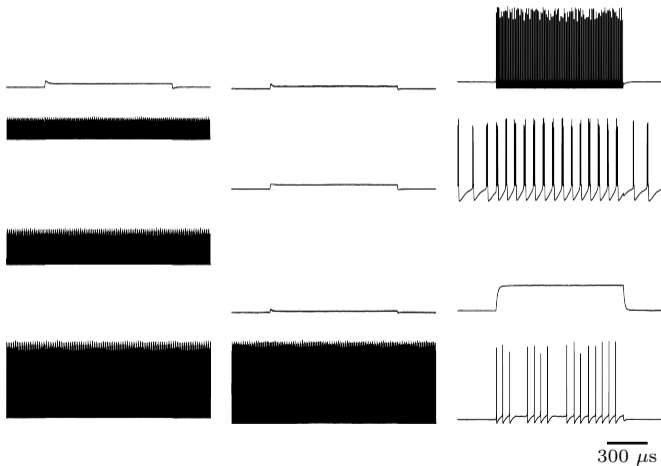


Uniform Prior

- $\theta \in \mathbb{R}^7$
- uniform prior over whole configuration space
- 50 000 samples

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Uniform Prior + Binary Classifier

- train binary classifier on number of spikes N_s :

$$B(\theta) = \begin{cases} 1, & 1 \leq N_s \leq 70, \\ 0, & \text{otherwise.} \end{cases}$$

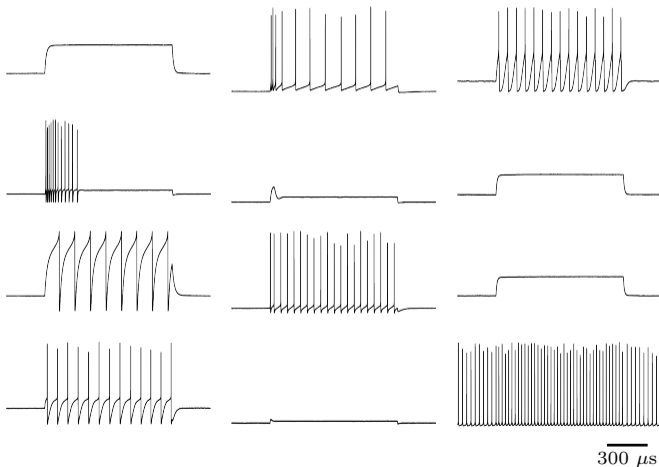
- uniform prior + binary classifier
- aim for low false negative rate
- 600 000 samples

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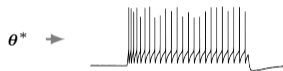
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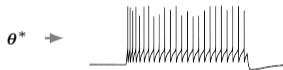
Posterior Distribution

- train two NDEs
- generate observation:

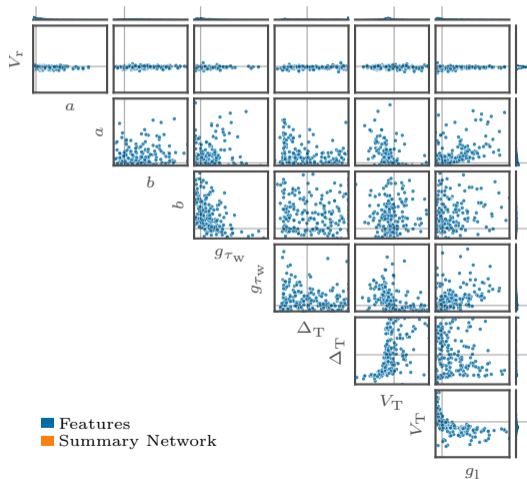
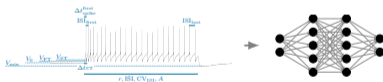


Posterior Distribution

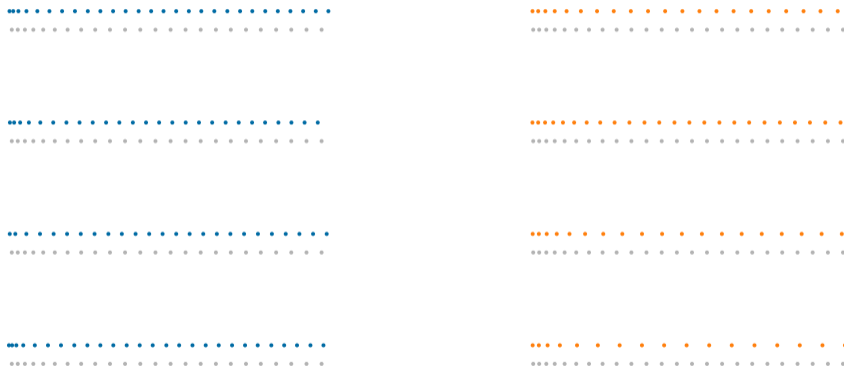
- train two NDEs
- generate observation:



- Features:



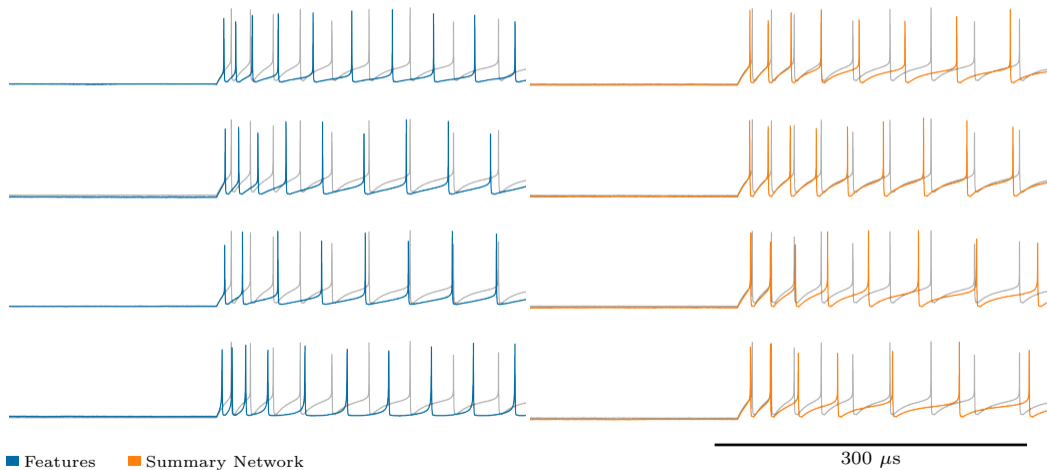
Posterior Predictive Outputs



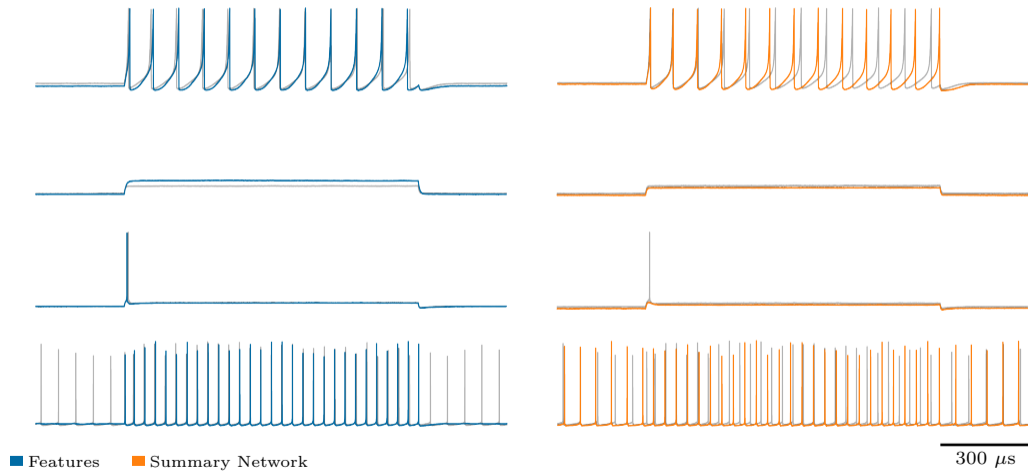
■ Features ■ Summary Network

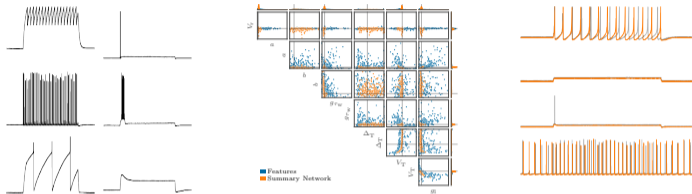
300 μ s

Posterior Predictive Outputs



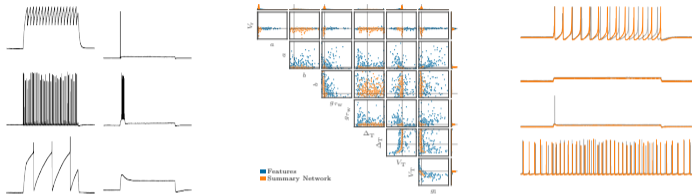
Different Target Observations





Outlook:

- more quantitative evaluation, e.g. calibration of the posteriors
- infer parameters from electrophysiological data, e.g. from the Allen Database

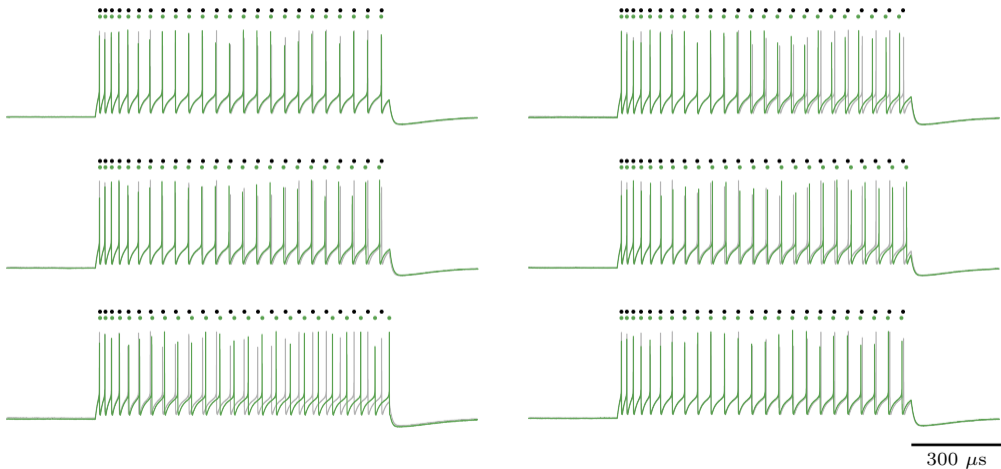


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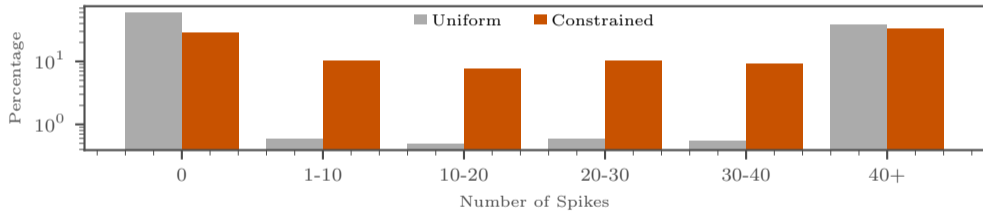
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BrainScaleS-2 Tutorial
tomorrow, 8:30 a.m.

Temporal Noise



Dataset



Predictive Posterior Check

